Alberta Environment
Regional Services

Controlling

STREAMBANK EROSION

Publication No. T/648
ISBN No. 0-7785-2143-5 (Printed Edition)
Online http://www3.gov.ab.ca/env/water/reports/riverchannelprocesses.html

CONTROLLING STREAMBANK EROSION

A Property Owner's Guide to Streambank Erosion Protection Methods
These notes present information on ways to control stream bank erosion and are intended as general information to assist the public when considering such work. These techniques are most suitable for creeks and small rivers no more than 20 metres (65 feet) wide. If your erosion problem is along a larger stream professional assistance is required.

Alberta Environment presents this information as a public service. While all of these methods have been used to control erosion problems, no erosion control technique will ever be completely successful in all applications. There is no guarantee that a particular method will be successful. This is especially true for low cost, do-it-yourself projects. The information includes a description of protection methods, their advantages and disadvantages. Substantial cost savings may be realized if you have the necessary equipment and can do the work yourself or know someone who can do it for you. A section on winter ice problems has been included.

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BROKEN WEB LINKS
Every effort is made to maintain the links to other web sites. The majority of the links are to other government information WebPages.

LEGISLATION

Provincial
Provincial legislation, specifically the Water Act (Alberta) requires that **anyone planning to modify the bed or banks of any body of water must obtain an approval from Alberta Environment before proceeding with the work.** Controlling stream bank erosion is subject to the requirements of the Water Act legislation and the Public Lands Act. An application and regional contacts may be obtained from the Department's website at:
http://www.gov.ab.ca/env/water/legislation/index.html More details are in **Appendix 1**

Federal
Authorizations will also be required under the Fisheries Act and Navigable waters Protection Act. Both legislative Acts are Federal documents and are administered by **Fisheries & Oceans, Canada.**
Contact Information regarding the Federal Fisheries Act may be obtained from their website at:
http://www.ncr.dfo.ca/habitat/Law_Reg/english/index_e.htm

Contact information may be obtained about the Federal Navigable Waters Protection Act at:
http://www.ccg-gcc.gc.ca/cen-arc/nwp-pen/client_e.htm

Other
Approval from the local authority (City, Town, Village, County, Summer Village etc.) is also required

Authorizations from all three regulatory institutions **are required**

Great care must be taken by the applicant and their contractor to avoid Harmful Alteration, Disruption or Destruction of Fish Habitat (HADD) as specified by the Federal Department of Fisheries on the above website. This means unauthorized harmful alteration, disruption or destruction of fish habitat by any means. This includes any changes to the band or bed of any water body. Early and personal contact with the Department of Fisheries and Oceans, Canada is suggested for advice in this matter.

If you plan to carry out any work that will place material in or on the shoreline of any river or lake, initial **consultations** with the Alberta Government **are strongly recommended regardless of the perceived ownership of that land.** These consultations are with the Department of Sustainable Resource Development, Public Lands Division. The ownership of the land must be clearly established by all prior to any plans formulated. The regional office locations for such consultation may be found at:
http://www2.gov.ab.ca/home/Programs_and_Services/dsp_PS.cfm?PS=8201

A bound copy of the Alberta Water Act may be obtained from the **Queen's Printer** at:
10611 - 98 Avenue
Edmonton, T5K 2P7
J.J. Bowlen Bldg. Room 204
620 - 7th Avenue SW Calgary, T2P OY8 1
Ordered on the web at: **http://www.gov.ab.ca/qp**
Print or view the 106 page document at:**http://ww.gov.ab.ca/qp/ascii/Acts/WPD/W03P5.TXT**

BE PRO-ACTIVE: PREVENT EROSION PROBLEMS BEFORE THEY OCCUR

The risk of riverside erosion may be minimized before a problem develops by:

- Don't farm the land within six metres (20 feet) of the bank. The border area needs the protection afforded by permanent vegetation as the roots stabilize the soil to prevent bank slumping.
- Keep additional weight away from the bank. Piles of dead trees, debris, spoil banks and levees should not be placed closer than six metres (20 feet) to the bank. Also try to avoid operating farm equipment on this area. Additional weight placed near a bank weakens the ground and may cause it to break away and slip into the stream channel
- Don't let livestock overgraze the banks. The loss of vegetation and the trampling of the ground and collapsing the bank by livestock may contribute to serious erosion and pollution problems. If a stream is the main source of water for livestock, use fencing to control or limit the area where the livestock can reach the river. Preferable specific watering sites would be where the bank is not steep. This normally occurs at the inside of bends in the channel, where flow velocities are low. Fencing a 6 m buffer (above) and fencing a lane 15 m (50') wide allowing access to these watering sites is recommended where possible.

- Sediment bars, snags, stumps, debris drifts, trees, brush and other objectionable vegetation disturb the flow, often directing it against the stream banks. Therefore, any obstructions to flow should be removed from the stream channel. This is usually the first step undertaken in protection and, in many cases, may be the only measure needed. The whole set of permits is required to alter, disrupt or modify the channel in any manner, regardless of perceived ownership.
- Diverting surface runoff or drainage away from areas where bank erosion may become a problem. Water flowing rapidly down a steep slope will add to erosion problems caused by the stream. Installing a culvert or small drop structure dissipates energy and protects the bank where the diverted runoff will enter the stream.
- Installing subsurface drains where water is observed seeping from the bank. Subsoil moisture or groundwater seepage may loosen and carry away the soil.
- Maintain all vegetation in a healthy state and avoid removing any vegetation along the stream bank where possible.
- Discourage beaver predation of trees by wrapping the vulnerable trees with wire mesh, at least 1 m (3') above the ground

BEFORE YOU START...

Trial and error solutions to erosion problems may eventually work, but can be very costly, frustrating, and time-consuming process. Here are a few basic concepts to consider before starting your project:

1. Try to identify exactly what changes have occurred along the stream bank over the past few years. Discussions with neighbors or long time residents may be useful. Old pictures available may assist in determining the location and rate of bank erosion. This may help in trying to predict its future movement and problems.
2. Is the project you're planning likely to cause new problems? Will the plans you have made be adequate? For example, if your project constricts the size of the channel it can cause flooding upstream. Also, a flow constriction might make the water flow faster, which can cause worse erosion problems downstream. Remember protecting stream bank often requires a considerable effort, often with very large and strong materials. Professional assistance may be required for initial advice or recommendations. You are about to embark on a complicated and probably very expensive repair. Make sure you are up to the task
3. Does the stream carry a lot of floating logs or debris, or have a moving ice cover during spring breakup? If so, be sure you choose a control method that isn't easily damaged by these kinds of hazards
4. All streambank protection projects should begin and end at stable points along the bank. These are areas which have not been subject to erosion, or which are formed of naturally erosion resistant material. Usually, this means a point at which the main thrust of the flow is parallel to the bank. When building your project, start at the upstream end and work your way downstream. This is particularly important if your project is being done in stages.
5. Whatever method you use to protect the bank, it should have a surface as rough or rougher than the natural channel. This slows the flow velocity near the bank, reducing the erosive attack on the bank material

6. Make the necessary provisions for routine maintenance of your project. Flood and erosion damage must be expected from time to time with any erosion control method. This means having the proper materials readily available to conduct quick repairs. Inspect your project regularly. It is especially important to check the bank after floodwaters go down. Make necessary repairs before the next flood.

REPAIRING STREAMBANK EROSION

These notes contain information on several methods recommended for use on Alberta rivers. The method you select will likely depend to a great extent on the resources available to you (money, construction materials, experience, available equipment and time). Advice from a Professional Engineer and/or Professional Biologist is strongly recommended.

The level of protection achieved will largely depend upon the method you select. In general, the more expensive the project, the more dependable and maintenance free it will be, if properly constructed.

Five methods of repairing stream bank erosion which have had success in Alberta are:

1. **Reshaping the mildly eroding bank;**
2. **Vegetating the sloped bank;**
3. **Protecting the stream bank with armour material;**
4. **Protecting the bank with armour rock groynes (spur dikes); and**
5. **Protecting the bank with gabion construction.**

Other methods used to control stream bank erosion are used tire breakwaters, gabion baskets and timber retaining walls. These designs and some of the above (#4 & 5) methods are more complex, requiring more time, equipment and the advice and perhaps designs of a Professional Engineer and/or Fish Biologist.

The information contained herein includes a description of the protection method, its advantages and disadvantages. Where possible approximate estimates of the associated costs (in 2001 Canadian dollars) is provided to hire a contractor to do the work. These costs are approximate and can be expected to vary depending upon your location, the actual size and most important the complexity of the project. Some cost savings may be realized if you have the equipment and can do the work yourself. Please remember these designs and costs are generalized and intended only as a guideline.

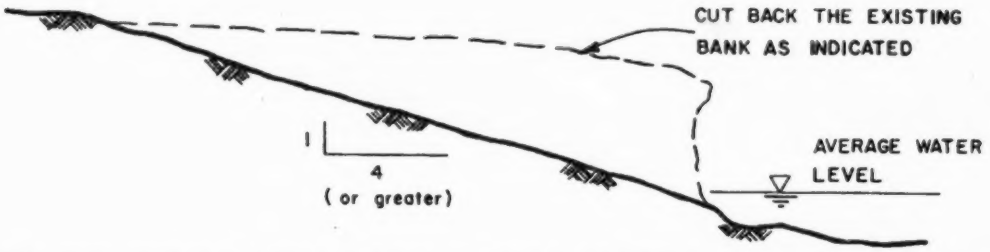
HIGHWOOD RIVER NEAR HIGH RIVER OCTOBER 1988

A WORD ABOUT MEASUREMENT UNITS

Throughout this brochure, the Metric system of units is used. For convenience the equivalent dimension in English units is provided as well. For further reference, the following conversion information is provided: 1 metre (m) = 100 centimetres (cm) = 3.3 feet (ft) = 39.4 inches (in)

METHOD 1
RESHAPING THE MILDLY ERODING BANK

In cases where the river bank is relatively stable and the erosion problem is not severe, reducing the bank to a more gradual slope means the removal of material that would otherwise have been eroded. This is the least expensive method of controlling stream bank erosion. The preparation of the bank is about $250 or more per lineal metre or $80 per foot. The preparation of the shoreline would cost about $75 per lineal metre ($25 per foot) of shore line, while the protection of the toe wold cost about $175 or more per lineal metre or $60 per foot. Frequent maintenance of the resloping is required. Repair work will likely be necessary after each significant flood or storm.



The more gradual the slope, the less material is available to erode and the more stable the bank will be. While there are never any guarantees with nature, a slope of at least three metres of horizontal distance for each metre of vertical drop (a three to one slope) is recommended. To construct this new slope, it is much easier to cut back the existing bank, rather than to build outward using fill. A slope made of fill is more easily eroded than one that is cut into the native stable soil.

METHOD 2
VEGETATING THE SLOPED BANK

The construction procedure consists of three parts. **First**, the bank must be reshaped to a more gradual slope. In this case it is recommended that it be cut back to a three to one slope, or flatter. **Second**, the toe of the slope must be fully protected. **Finally** vegetation must be established and watered frequently for several months until the growth catches.

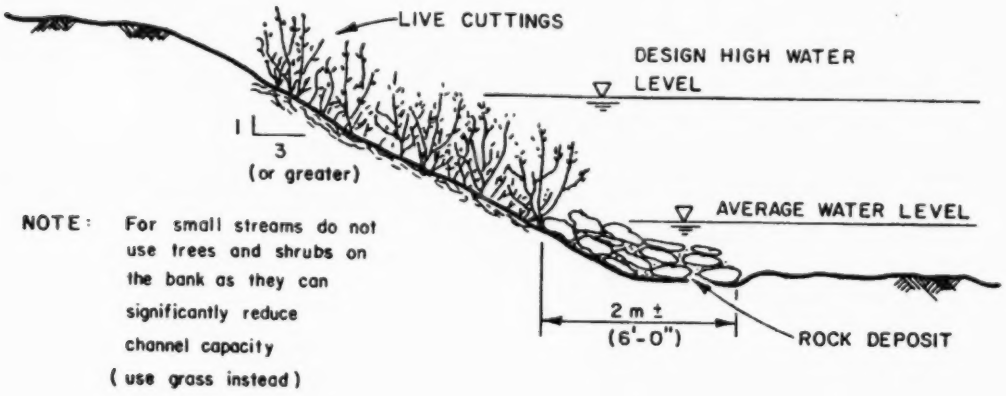
Once the bank has been sloped, similar to Method 1, it should be covered with erosion resistant material, such as vegetation, matting, boulders or angular rock because a bare slope is more susceptible to additional erosion. Establishing grasses, shrubs and/or trees on the bank will enhance long-term stability. With creek channels less than 2 metres in width, trees planted at the waters' edge will spread in all directions. This expansion of tree cover could choke the creek channel, cutting off major flows.

The additional cost of establishing vegetation on the bank is difficult to quantify, as most of the expenditure would be for labour and watering. Once the vegetation becomes strongly established, the protection should be relatively maintenance free if erosive forces remain very low. It is wise to resist trimming these streambank vegetation and grasses.

Protecting the Toe of the Bank

The toe of the slope is the part of the bank that is submerged during most of the growing season and will scour (erode) on the outside of a bend in a river due to recurring high water events. Generally this shore line area will not sustain a protective vegetative cover. However, protection of the bank below this waterline is the main key to successful bank stabilization, because it prevents further scour and undermining of the bank.

The main cause of riverbank failure is the erosion of the material at the toe of the slope. With this toe material washed away, there is no support for the overlying bank material and it collapses into the river. This process is repeated continuously, varying only when discharges change. In this case, the coarseness of the toe material and its resistance to erosion is the determining factor in bank stabilization. Once the toe of the bank is stabilized, the stream can no longer carry soil away from the base, undercutting is stopped and eventually the bank reaches a state of equilibrium where slumps and slides no longer occur. As soil movement ceases, vegetation becomes established on the bank, helping to hold the soil in place.


LIVE CUTTINGS
DESIGN HIGH WATER LEVEL
1
3
(or greater)
AVERAGE WATER LEVEL
NOTE: For small streams do not use trees and shrubs on the bank as they can significantly reduce channel capacity (use grass instead)
2 m ±
(6'-0")
ROCK DEPOSIT

To protect the bank, place large rock along the toe of the bank. Armour rock may be grouped into size classifications as indicated below. The size of the rock required depends on the water velocities against the toe of the slope. These velocities are in turn determined by flood discharges and the river bed slope. Ideally these rocks should be very angular. The size of the rock will depend on the depth of flow and severity of bend in the river with at least Class 2 size required in most sites. To protect this lower portion of the slope, the deposit should be at least two layers thick (twice the mean diameter of the rock) and should extend about two metres (six feet) out into the channel. To eliminate any obstruction to the flow within the channel, this apron rock may be buried in the riverbed in a small trench excavated for that purpose. Without an armour rock apron, bank protection will almost certainly fail. The preparation of the bank would cost about $120 per metre ($40 per foot) of bank, while the protection of the toe would cost from $250 to $1000 per metre ($80 to $350 per foot), with the armour rock costing about $120 per cubic metre in place.

CLASSIFICATION OF ARMOUR ROCK SIZES

Class 1 rock... 20 to 45 cm (8" to 18") or 10kg. to 130kg. (25# to 300#)
Class 2 rock... 30 to 80 cm (12" to 30") or 40kg. to 700kg. (80# to 1500#)
Class 3 rock... 50 to 1200 cm (20" to 48") or 200kg. to 2400kg. (4000# to 5200#)

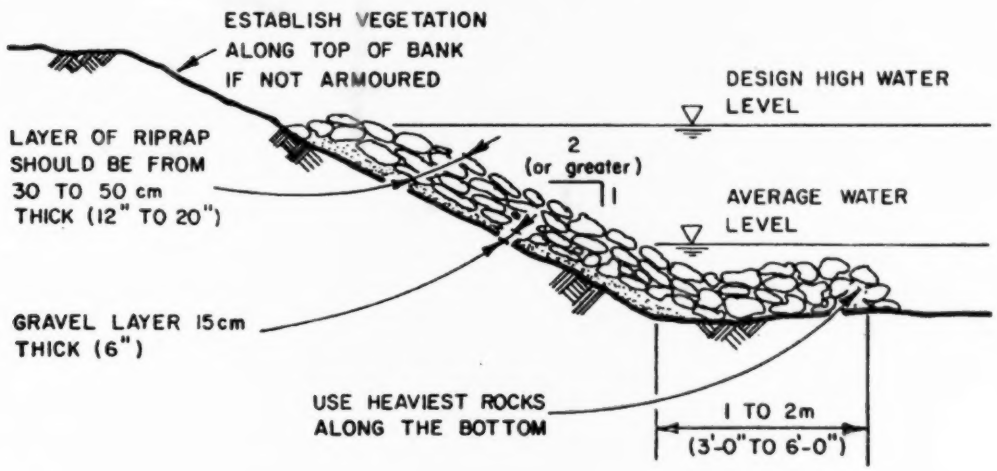
If only small (4' to 8"rounded) rock is available, gabion baskets are an excellent choice. However their life span may be limited to 20 years or less due to ice and floating debris tearing the woven wire mesh as the debris is carried downstream. Further Information about gabions and their applications is available at **http://www.maccaferri-canada.com**.

Broken concrete may be substituted (if the pieces are large enough), but only if all the protruding reinforcing steel and debris (waste construction material, silts, small gravel) is removed prior to installation. Smooth rounded fieldstone or rocks found in the river regardless of size are not recommended due to their ability to roll and slide in strong currents.

Establishing Vegetation on the Bank
Grasses should be established on the banks of smaller streams where trees and shrubs would reduce the channel capacity. In all other cases, trees and shrubs would be preferable as their root systems stabilize the soil, offering greater protection. A more complete discussion of planting and maintaining vegetation on the river bank is presented in **Appendix 2.**

METHOD 3
PROTECTING THE RIVER BANK WITH ARMOUR MATERIAL

In cases where the attack on a bank is severe, armouring the entire the bank will provide superior bank protection. This bank protection consists of placing 2 layers of rocks (or equivalent material) on a sloped bank, similar to Method 2. This method of bank protection must have a filter (gravel or cloth) between the rocks and the prepared slope to keep the fine materials from leaching from the bank into the water body. This type of protection has a rough natural appearance and adjusts itself to the shape of the bank.



First the bank is reshaped to a 3 or 4 to 1 slope. Then a gravel filter is placed on the sloped bank. This filter can be either a filter cloth or a layer of coarse gravel at least 20 centimetres (eight inches) thick on the slope. Without this filter layer, fine-grained material making up the bank will erode through the armour layer, causing the armour layer to collapse and fail. Finally armour rock with a Class II gradation is placed on the filter, and extended into the water body, as in Method 2. To complete the work both ends of the bank protection should be turned inward into the bank ad extended about 2 metres (6 feet) into the bank, for the full height of the protection. This "keying" into the bank will prevent the risk of erosive forces outflanking the protected bank. Or narrow rive lots, the cost of this protection can be a substantial proportion f the total cost. Co-operative action with adjacent land owners would eliminate the need for "keying in" at every property line.

The approximate cost of grading the bank to a three to one slope would be about $250 per metre along the bank ($80 per foot). The additional cost of the filter layer would be approximately $50 per metre ($15 per foot). The cost of the armour material itself would depend upon the height of bank and type of material used. As an indication, the cost of quarried rock could be around $120 per cubic metre in place or in the order of an additional $250 to $1000 per metre of bank ($85 to $330 per foot). Although very expensive, this form of protection can be expected to require very little maintenance even under severe attack if the rock sizes are large enough. Some cost savings may be achieved by substituting other armouring materials. Materials with lesser durability will produce less durable results with more maintenance required. Gabions installed by a contractor cost in the order of $150 per cubic metre plus the cost of the rock. Since this is very manual labour intensive, costs may be reduced if the owner undertakes much of the work and finds a very economical source of 4" to 8" cobbles.

Choosing the Right Materials

The very best materials to use for riprap are broken limestone, dolomite, or quartzite because of their high density and resistance to weathering. These are available from most quarries and consist of roughly broken or blasted stone. The rough angular surfaces and the variety of sizes help the rocks fit tightly together to form a dense barrier.

In some cases, the cost of quarried rock may be prohibitive and you may want to consider some less expensive substitutes. Desirable characteristics include weather resistance, rough angular surfaces and a variety of sizes.

- Fieldstone may be available locally and can be inexpensive. Although most fieldstone may not be large enough to withstand very high erosive attack, it can be used for low to moderate protection. The main objection to using fieldstone or rounded rock is the rounded shape, which rolls and slides easily when submerged and subject to a strong current. This type of rock is not recommended in most cases.
- Gabion baskets have been used Gabion baskets have been used and other gabion-like products will work well in moderate erosion circumstances. However their life span in Alberta is limited to 15 - 20 years due to moving ice breaking or tearing the woven wire mesh during spring break up. Where gabions are not subject to ice shove or abrasive action of a flowing current, they function well.
- Broken concrete may be used only if the reinforcing steel is cut off level with the concrete. Concrete poured into block shaped pieces is excellent, although expensive.
- Sandstone or flagstone may be substituted as well, however they are not as durable as quarried rock when exposed to water. The normal procedure is to increase the size requirements and volumes by at last 30% to allow for weathering over time.

Retaining walls and armour rock spurs (groynes) have had success sin Alberta, and can be less expensive than Method 3. Repairs to these structures can be difficult. Professional assistance is recommended with the design of such projects..

Although only by your imagination and ingenuity limit the scope of suitable substitutes, common sense is essential. Materials that **cannot** be used include:

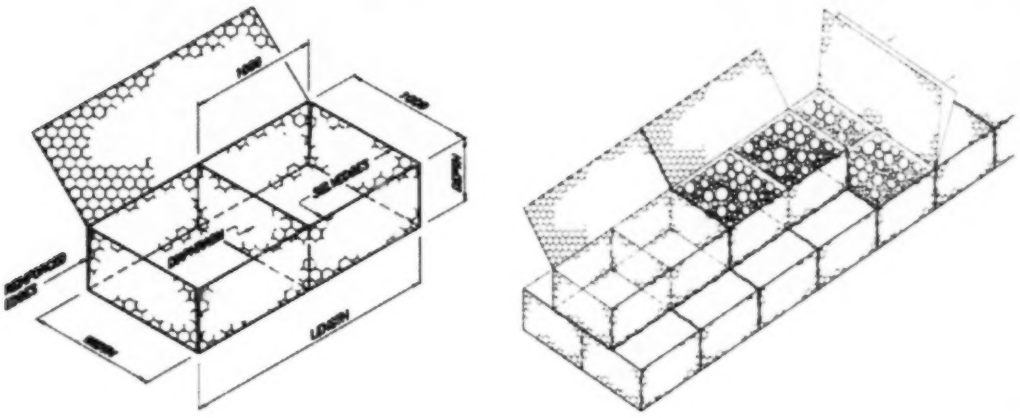
- Broken asphalt is not dense enough and it is toxic to fish.
- Rubble from the demolition of buildings due to the public safety hazard.
- Junk such as washing machines, refrigerators, bedsprings and car bodies due to a source of toxicity and public safety hazards.

Placing the armour material

The largest, heaviest rocks should be placed along the toe of the slope. If the rocks protect only the lower portion of the slope, vegetation should e planted in the upper exposed area. This will prevent rainfall from creating small gullies (1-10 cms or up to 50 cm wide) on an exposed slope.

The stream will tend to deepen (or scour) after the bank is armoured, especially during floods. To protect this bottom area an apron must be constructed out into the river at least one to two metres (three to six feet) and be about 0.5 to 1.0 metres thick. The construction of an armour rock apron is essential. If it is not done, the bank protection work will almost certainly fail. The main mechanism of bank failure by erosion occurs at the toe of the slope during most discharges. If rocks are placed at the toe of the slope, the bed material beneath them will erode somewhat until the rocks in the apron fall down into the scour hole formed by the river. In this way, the apron protects the bank protection by protecting the toe of the slope, about 2 metres out into the river. To ease the passage of flow in a river, the apron may be buried flush with the bed of the river such that none of the rocks protrude into the flow causing a disturbance or reducing the carrying capacity of a river cross section.

METHOD 4
CONSTRUCTION OF GABION PROTECTION



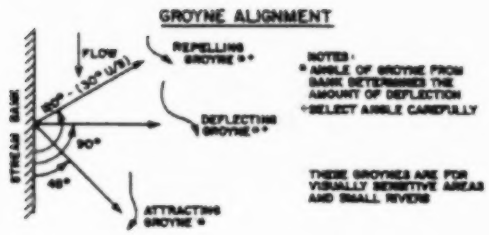
This construction method utilizes square baskets filled with smaller rock (5" to 9") rounded rock. For this application typical basket sizes are in the order of 1 m wide, 2 m long and about 1 m deep. The baskets are wired together to form one large interlocking structure. More details on gabion products and various products that may be used for this application may be found at: **http://www.maccaferri-canada.com**. As in the previous example, an apron at the toe of the slope is essential and is made from gabion baskets or a combination of gabion baskets and large armour rock. Due to the construction methods, the gabion baskets do not move and consequently will not launch into a scour hole when one forms. Thus the inclusion of large armour rock to fill in the scour holes when they do form. If too much of the rock launches out into the river, additional armour rock may be added to make up the deficiency.

The overall appearance of the structure is relatively smooth. The only limitation utilizing gabions is the wire mesh being broken by floating debris or ice breakup in the spring.

METHOD 5
CONSTRUCTION OF GROYNE PROTECTION

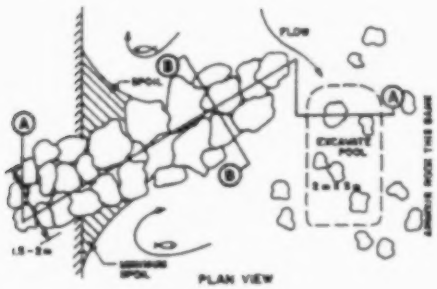
Groynes or spur dikes are considered a relatively advanced design and normally should be left to a professional consultant. For the purpose of information, an outline of this design will be covered in this section. The design of the structure is one matter, its placement in the stream is another one entirely different, both of which are required for a successful structure.

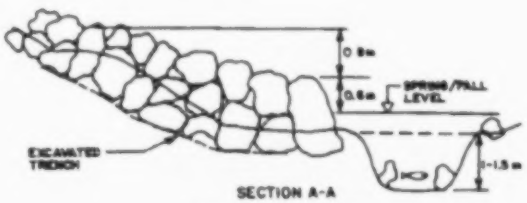
This structure in its essence is a finger of large armour rock that protrudes out into a river. The angle of placement, 30^0 downstream, 90^0 to the current or 30^0 upstream will determine whether the groyne will attract pass or repel the oncoming current from the bank. In most applications the latte two are the only alignments used. To point the groyne downstream actually pulls the current in toward the bank, sometimes resulting in bank erosion.



The design of the groyne begins with the selection of the proper rock size classification. If the river requires a Class II armour rock to protect the bank, then the groyne should be a minimum of Class III rock with at least 6 oversize rocks (1.6 –2 m). This rock selection is critical as each rock in the groyne will repel the current on its own, especially the point rocks. All the smaller rock will be swept away during a large flood. The groyne is designed to be overtopped, which considerably reduces its height, but requires large rock. The angle at which the groyne will be placed must be selected at this time.

Field construction requires a large key way into the bank of at least 2 metres, or more on a large river. The weakest point of a groyne is where it meets the bank. Currents can get in behind the rock, creating a small channel between the bank and the groyne. The rock is then piled outward from the bank with some of the smaller rock placed in the key trench and in the bottom layer of the groyne. The largest rock is usually reserved for the outward tip of the groyne where the erosive forces are the strongest. The final top width is about 2 metres and the height normally ranges about 2-3 metres in most installations





REPELLING GROYNE

WINTER ICE PROBLEMS...some notes

A problem during spring breakup with ice movement is the destruction of docks and damage to bank protection installed. At this time, the moving ice will gouge portions of the river bed and banks, damaging any structures located too close to the river's edge.

It has been experienced that during fall freezeup that ice will freeze solidly to the river banks and any angular armour rock protection. During spring breakup, the ice will take some of the rock with it, scattering it along the river bed. In this situation, only large armour rock bank protection will withstand the ice movement to any degree of success.

The problem of ice jamming on rivers generally does not happen except at specific places along a river. History will indicate where such problems exist on a regular basis and how far to stay back from the river at that location. To a large degree ice jams can only be managed, never solved.

During intensely cold winters, sometimes ice will freeze to the river bed of small rivers & streams. If underground springs are flowing in the area, the seepage from these springs or other overflows may move onto the surface of the ice. With sufficient flow, sometimes rivers can be forced out of their banks

APPENDIX 1

THE ALBERTA ENVIRONMENT WATER ACT APPLICATION

The application for an approval consists of:

- The application form itself containing - name and address of applicant; - legal description of the location of the proposed project; and other related information.

- Plans, reports, specifications and other supporting data explaining the project are essential. The advice and assistance of a professional consultant is highly recommended. This information is required to evaluate the effect of the project on the water body and adjacent land parcels.
- A large or complex project may require a report prepared by a Professional Consultant. Contact the regional office for advice in this matter.

APPLICATION REVIEW

Staff from the Regional Water Management team or administration will review the completed applications, including plans. Among the points examined are:

- The ownership of the land involved and consents of neighbouring landowners. If the works involve other parties the applicant must consult with their neighbours and obtain the required consents.
- The effect of the proposed project on other landowners, the aquatic habitat, the water resource itself as well as other projects.
- Additional information, if required.
- Referral to other Government departments for concerns including Public Lands Division, and Fish and Wildlife, Division of Sustainable Resource Development.
- Referral to other authorities – municipal governments, drainage and irrigation districts, Water Ace License holders and others that may have concerns. The views of other authorities - municipal governments, irrigation districts and others that may have concerns;
- Public notice requirements;

Application forms and information are available at:
http://www.gov.ab.ca/env/water/legislation/index.html

For further information, contact the River Engineering Branch at (780) 427.6280 or by email through **Bob.Quazi@gov.ab.ca.** The contact address is River Engineering Branch, 9th floor, 9820 – 106 St. Edmonton, Alberta, T5K 2J6.

APPENDIX 2...Additional Information

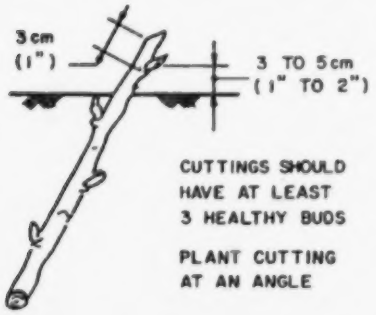
ESTABLISHING VEGETATION

Grasses should be established where trees and shrubs are considered aesthetically unacceptable. In all other cases, trees and shrubs are preferable as their root systems stabilize the soil, offering greater protection. Information on native plant revegetation may be obtained from the Alberta Department of Agriculture, Food and Rural Development at
http://www.agric.gov.ab.ca/publiclands/nprg/col_index.html.

Along the highways and other areas that require a fast strong ground cover, a mixture of clover and alfalfa is used extensively. The clover, which develops quickly, has a dense root system near the surface. The slower growing alfalfa has a deep root system.

However for a river bank project, dogwoods are good shrubs for bank protection. The best trees are cottonwoods and willows. They can be planted as cuttings and will grow relatively fast. You can get cuttings from a nursery or you can take them from plants in your area during the spring, before the leaves come out. To do this, take the cuttings from the latest growth - the new wood that grew during the previous season. The cuttings should be from 25 to 40 centimetres long (I 0 to 15 inches), and from one to one and one half centimetres thick (three eights to one half inch). Be sure to use a sharp knife or pruning shears so that you don't bruise the bark.

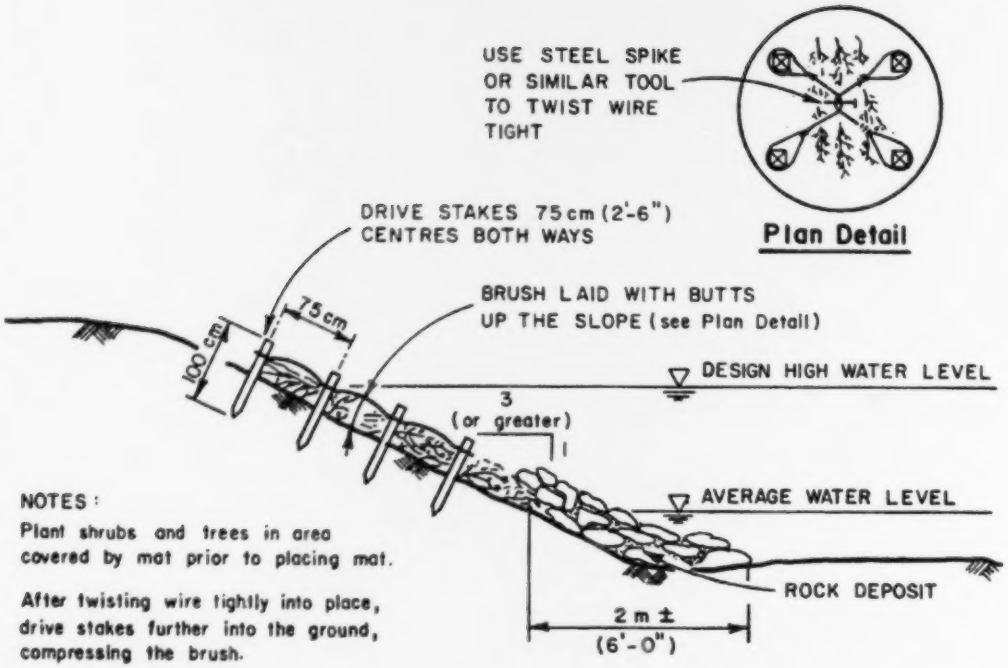
Each cutting should have at least three healthy buds on it. Since the ends may dry out, the cuts should be at least three centimetres (one inch) away from the highest and lowest buds. Keep the cuttings moist and plant them as soon as possible.



Being careful not to injure the buds, plant the cuttings with the buds pointing up. The topmost bud should be three to five centimetres (one to two inches) above the ground. Space the cuttings about 60 centimetres (two feet) apart in staggered rows.

Protecting the Vegetation

The new plantings will have to be protected from the high stream flows of early spring. Immediately after planting, cover the area with five to 10 centimetres (two to four inches) of mulch. Straw or hay, applied at a rate of 50 kg per 100 square metres (or 100 lbs per 1000 square feet), is commonly used. To hold the mulch in place, cover it with some type of netting. Make sure the mesh is the right size to retain the type of mulch you are using and anchor the net securely to the bank. A brush mat (as shown in the diagram below) will serve the same purpose.



In some cases, brush mats may be used alone as bank protection. Although they eventually deteriorate, they allow eroded areas time to restabilize through natural vegetation re-establishment. They encourage vegetation growth (whether planted or naturally occurring) both by protecting plants from high flow velocities and by encouraging siltation in the voids.

For further information

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ISBN No. 0-7785-2143-5 (Printed Edition)
ISBN No. 0-7785-2144-3 (On-Line Edition)
Pub. No. T/648